

DIBROMO-CHLOROPROPANE SOURCE DEFINITION,  
ROCKY MOUNTAIN ARSENAL, COLORADO

PHASE I

by

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and  
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Prepared by

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US Army Engineer Waterways Experiment Station  
PO Box 631, Vicksburg, MS 39180-0631

September 1984

Prepared for

US Army Toxic and Hazardous Materials Agency  
Aberdeen Proving Ground, MD 21005

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## PREFACE

This study was conducted during the period 19 May 1984 to 30 September 1984 by personnel of the Engineering Geology and Rock Mechanics Division (EGRMD), Geotechnical Laboratory (GL), of the US Army Engineer Waterways Experiment Station (WES), in support of Project R01 - Rocky Mountain Arsenal (RMA) - Task R011.01.7005. Funding for this study was provided by Commander, US Army Toxic and Hazardous Materials Agency (USATHAMA), via Intra-Army Order No. 84-D-9.

This report was written by Mr. C. B. Whitten and Mr. J. H. Shamburger, Engineering Geology Applications Group (EGAG), EGRMD, GL. The study was under the direct supervision of Mr. J. H. Shamburger, Chief, EGAG, and the general supervision of Dr. D. C. Banks, Chief, EGRMD, and Dr. W. F. Marcuson III, Chief, GL.

Special acknowledgement is extended to Mr. Edwin W. Berry, RMA, for providing recent water quality data from existing wells included in the RMA's study entitled "Evaluation of Shell Chemical Company's Ground-Water DBCP Control System" for input to the plume map prepared in this study; Dr. Mike Witt, RMA, for providing DBCP analysis of water samples collected in the wells installed during this study; and Mr. Charlie Scharmann, USATHAMA, for his assistance in all phases of the study.

Commanders and Directors of the WES during this study were COL Tilford C. Creel, CE, and COL Robert C. Lee, CE. Mr. F. R. Brown was Technical Director.

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PART I: INTRODUCTION

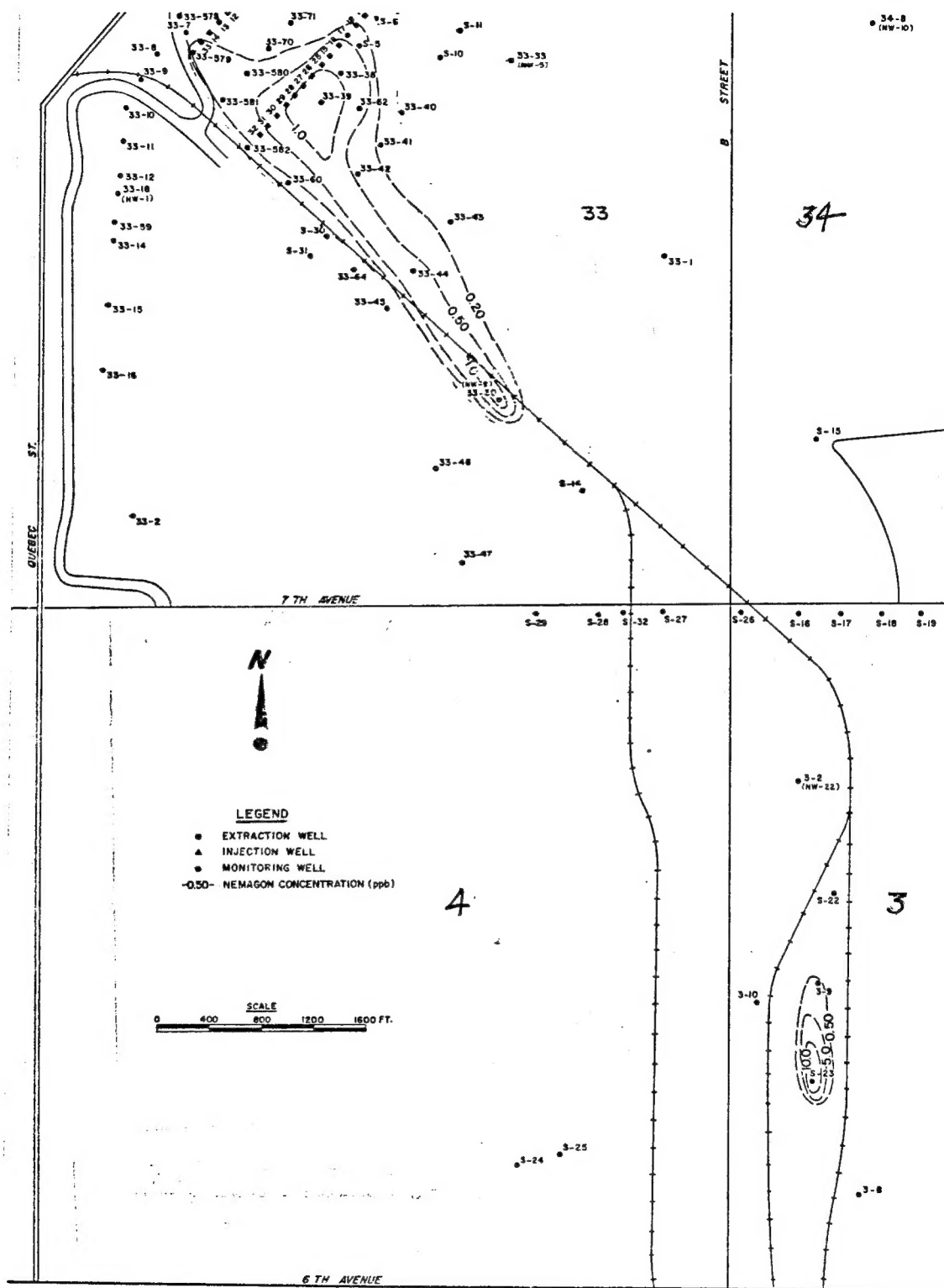
Background

In March 1980, Dibromo-Chloropropane (DBCP) or Nemagon was discovered in water wells in the Irondale community, which is located adjacent to the northwest boundary of Rocky Mountain Arsenal (RMA). The RMA and Shell Chemical Company (SCC) initiated a coordinated program to identify the DBCP plume influencing the wells at Irondale. In addition, the SCC constructed a control system along the northwest boundary to stop the DBCP from migrating offpost. This control system consists of a hydrologic barrier, rows of extraction and injection wells, and a treatment system. An evaluation program was implemented by RMA and SCC to determine the effectiveness of the control system which would also define the route of migration of DBCP.

Two unconnected areas of high Nemagon concentrations were identified in existing wells during the evaluation study. One area is north of 7th Avenue with well 33-30 having the maximum concentration and the other area is south of 7th Avenue with well S-23 showing the maximum concentration (Figure 1). A possible reason for these two areas to appear separated is because the monitoring wells along 7th Avenue penetrate only 5 ft into the alluvial aquifer. Both areas are adjacent to railroad tracks where spills could have occurred and are underlain by a buried channel (Figure 1) that is incised in the Denver formation.

Purpose and Scope

The purpose of this study was to determine if the two areas of high Nemagon concentrations are from one source south of the railyard or if there are two sources - one south in the railyard area and a second source north of 7th Avenue. During the study data from newly installed and monitor wells along 7th Avenue between the two areas of high concentration in the buried channel and were used to supplement existing data.



## Approach and Rationale

### Approach

Cluster well sites were installed just south and along 7th Avenue and west of B Street. The screened interval of each well in each cluster was 10 ft or less and positioned so that the entire saturated thickness of the alluvial aquifer was screened. Water quality data from these wells were used to determine if one or two sources of DBCP were contributing to the ground-water contamination.

### Rationale

The rationale used to select the location of the five cluster well sites (a sixth site was added during the field work) along 7th Avenue was:

- a. Ground-water flow from the railyard area (Section 3) is to the northwest and crosses 7th Avenue in the area between wells S-29 and S-16 (Figure 1).
- b. An alluvial channel in the top of Denver formation extends between well S-23 and 7th Avenue, crosses 7th Avenue near well S-29, and continues to the northwest along the southwest side of the railroad in section 33.
- c. Nemagon was found in well S-27 in January 1982 (0.22 ppb) and in well S-29 in May 1982 (0.30 ppb) and September 1983 (0.22 ppb). The cluster well sites were positioned to sample the ground water flowing past 7th Avenue in the area indicated by the above criteria.

Because DBCP was found in wells S-27 and S-28 and the exact position of the buried alluvial channel under 7th Avenue was unknown, the first three cluster well sites were to be located between wells S-29 and S-26 (Figure 1). The first well cluster was to be installed 100 ft west of well S-28, the second cluster 100 ft west of well S-27, and the third set 300 ft east of well S-27. The depth to the Denver formation determined in the first boring in well clusters 1, 2, and 3 was used to locate the fourth cluster of wells as follows:

- a. 250 ft west of well S-16, if the alluvial channel or deeper portion of the channel was east of well cluster 3.
- b. 100 ft west of well S-29 if the alluvial channel or deeper portion of the channel was west of well cluster 1, or if there was a question about the location of the deeper portion of the channel.

## PART II: FIELD INVESTIGATION

### Drilling and Sampling

At each cluster site the first or pilot boring was drilled through the alluvium and about 5 ft into the Denver formation. In the pilot boring soil samples were taken with a split-spoon sampler at 5-ft intervals or at strata change. The pilot boring provided: (a) the lithology, (b) the aquifer thickness which dictated the number of wells to be installed, and (c) the location of the deepest well.

Five pilot borings (RSD 1-5) were drilled parallel and just south of 7th Avenue. Another well (RSD-6) was drilled south of 7th Avenue to determine the top of Denver and provide water quality data in an area that is void of monitoring wells (Figure 2).

### Well Installation

A total of 17 wells was installed at the six cluster sites. Figure 3 is a schematic of an installed well in a pilot boring. The other wells were installed similarly except for the screened interval depth and no soil samples were taken. At each site the aquifer was screened in 10-ft intervals until the entire thickness was screened. The wells in each cluster were spaced 10 ft apart and aligned perpendicular (NE-SW) to the ground-water flow. Table 1 presents data on elevation, water table, screened interval, and depth to the Denver formation.

### Water Sampling

Depth to the water table was measured in each pilot boring the day following well installation. Water sampling and a complete round of water table measurements were taken on 2 August 1984. The water samples were submitted to RMA chemical laboratory for analysis.

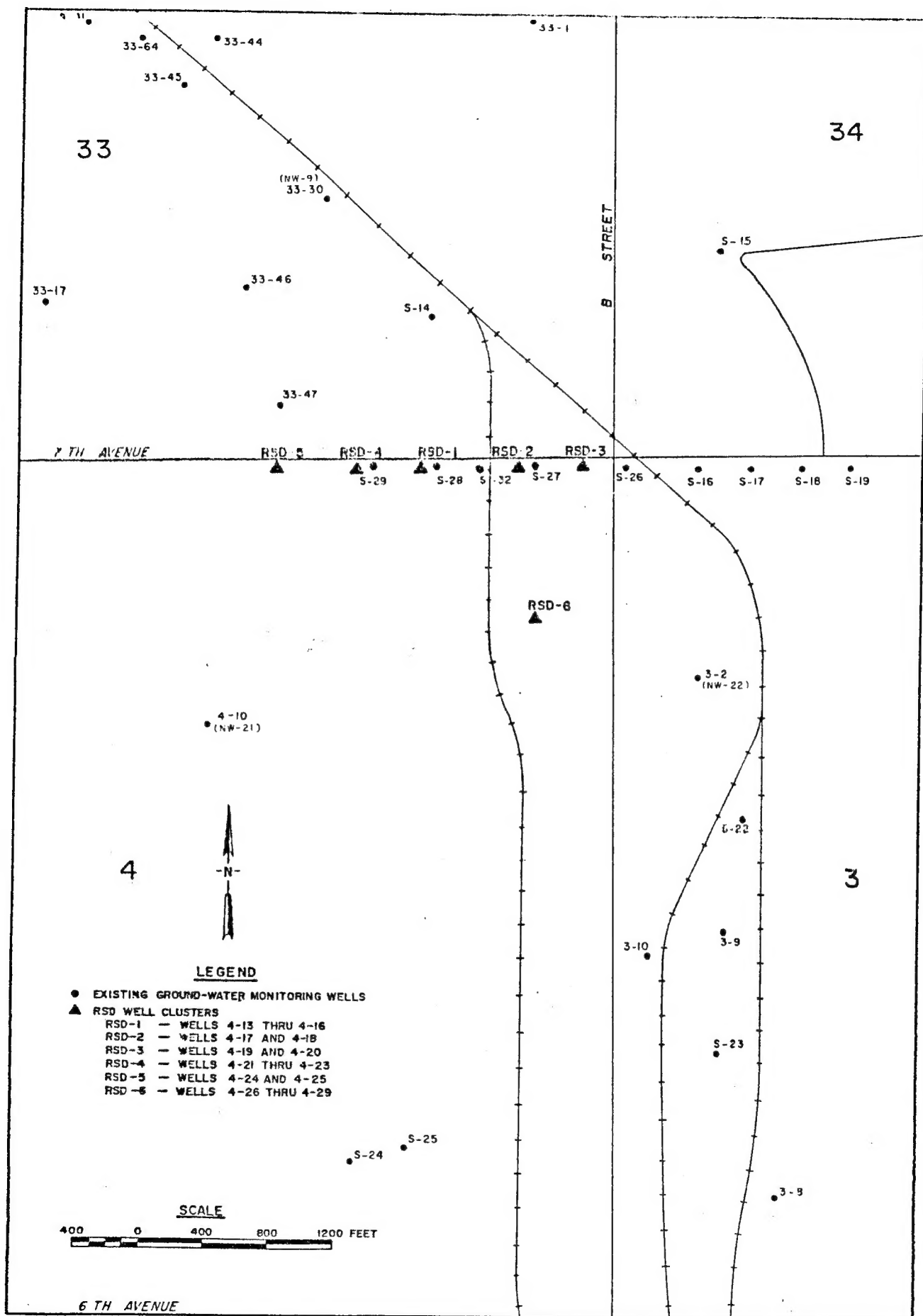


Figure 2. Boring and well locations

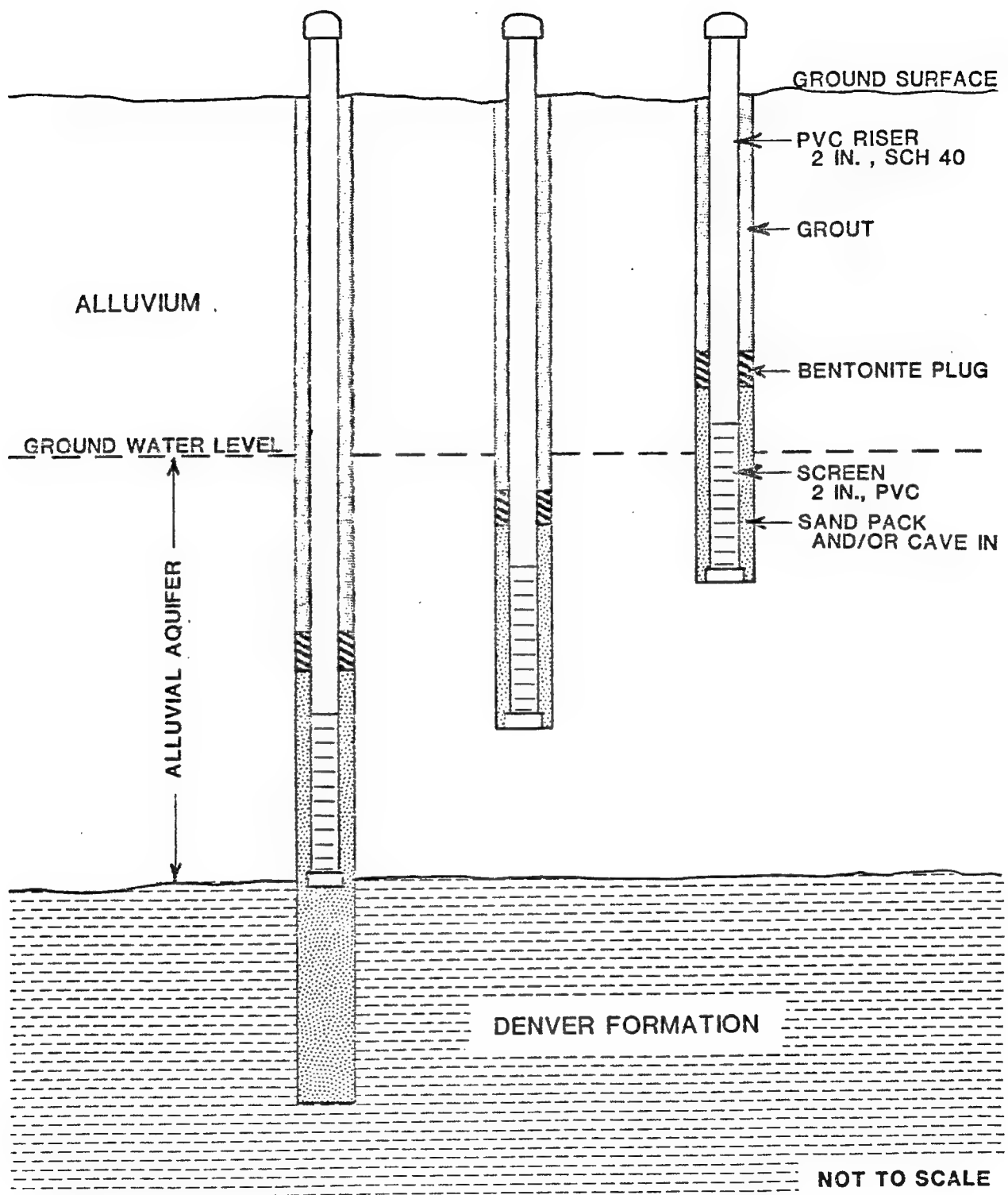


Figure 3. Schematic of cluster wells

### PART III: DATA ANALYSIS

The lithology from the borings and water depth from monitoring wells provided hydrogeologic information in an area where these data were needed. The water quality results enabled this study to reach significant conclusions. The analysis of the data collection is presented in the following paragraphs.

#### Hydrogeological Analysis

Figure 4 is a section of the subsurface lithology between RSD-5 and RSD-3. The alluvium is composed predominantly of coarse-grained soils--silty sands (SM) to sandy gravels (GP). Only one continuous layer of fine-grained soil (silt or clay) occurs in this section and the water table was in this fine-grained layer on 2 August 1984.

The alluvial aquifer varies in thickness from 19 ft to 34 ft and is composed almost entirely of a sandy gravel (GP) except for a few feet of silt, silty clay, silty sand, and sand at the top of the aquifer. The Denver clay shale which acts as an aquiclude underlies the aquifer. The deepest part of the aquifer occurs between RSD-4 and RSD-1.

The borings provided data points for determining the elevations of the alluvium/Denver formation contact which enabled the construction of definitive top of Denver map in the vicinity of 7th Avenue (Figure 5). Prior to the new control points the top of Denver portrayed an incised channel with a west-northwest trend from about 400 ft north of well 3-1 to 7th Avenue just west of well cluster RSD-1 where the direction changed to north-northwest to well 33-30. The revised map places the channel eastward between RSD-5 and RSD-2 with a north-northwest direction. The channel south of 7th Avenue is not as deep or as well defined with the current data points as it is north of 7th Avenue. This straighter channel configuration means that the flow direction of ground water in the channel is more direct from S-23 to 33-30 and the flow is slower between S-23 and 7th Avenue than previous believed because of a lower gradient.

Figure 6 is a water table map of the area between well S-23 and 33-64 (northwest of 33-30). This figure was prepared using water levels taken by RMA personnel on 26-28 June 1984 for all wells except the RSD wells where

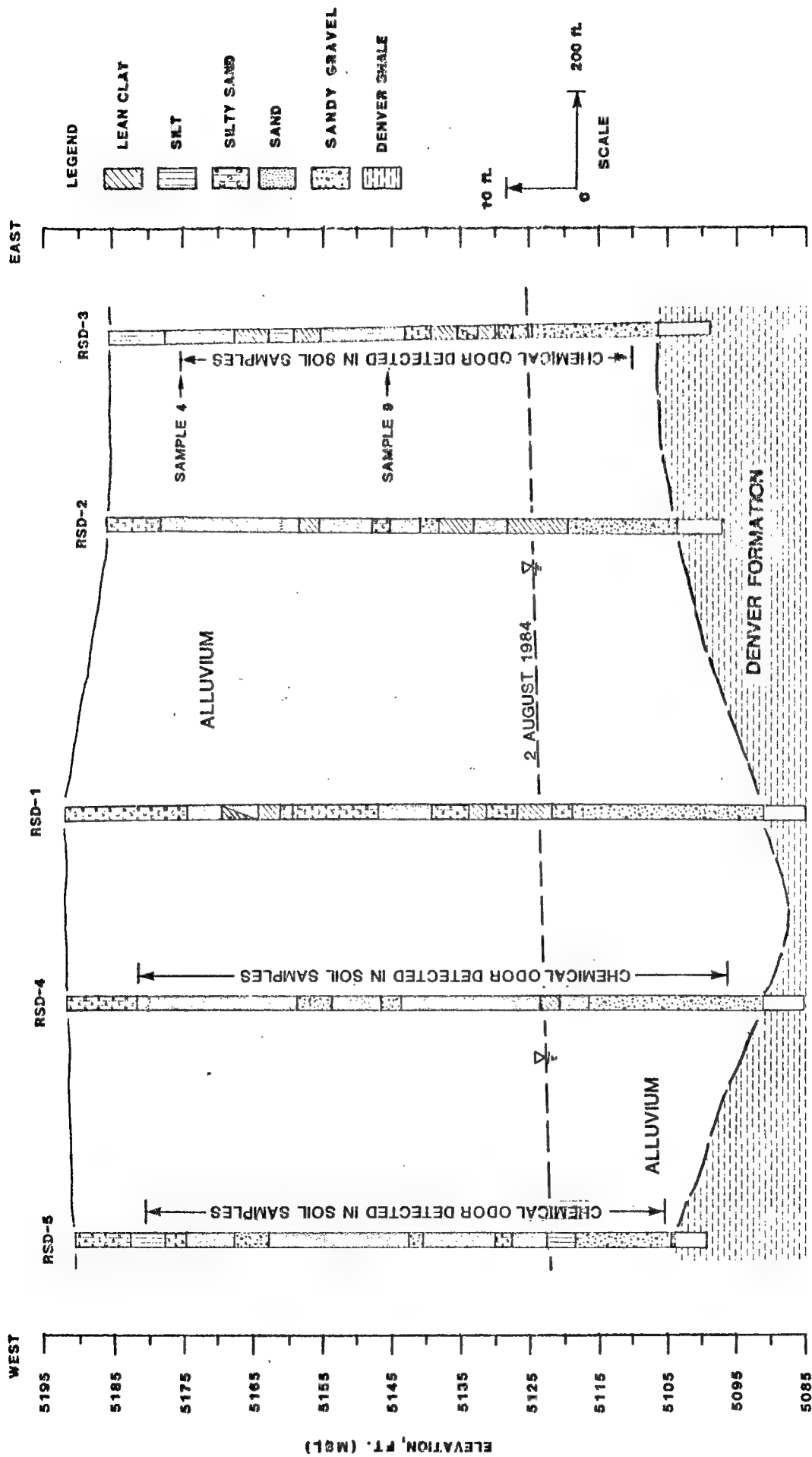


Figure 4. Geologic section along 7th Avenue

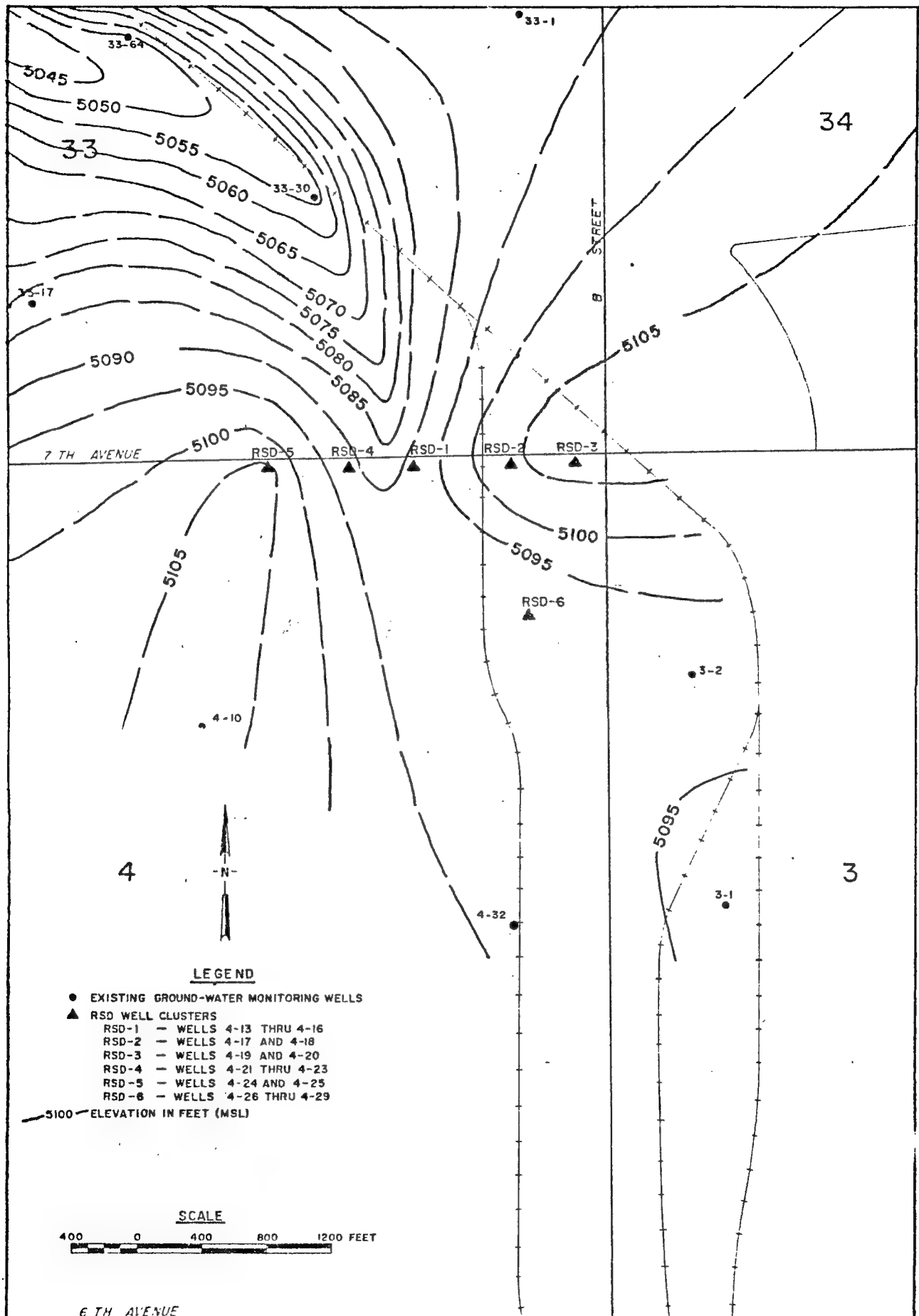


Figure 5. Elevation of the top of the Denver formations

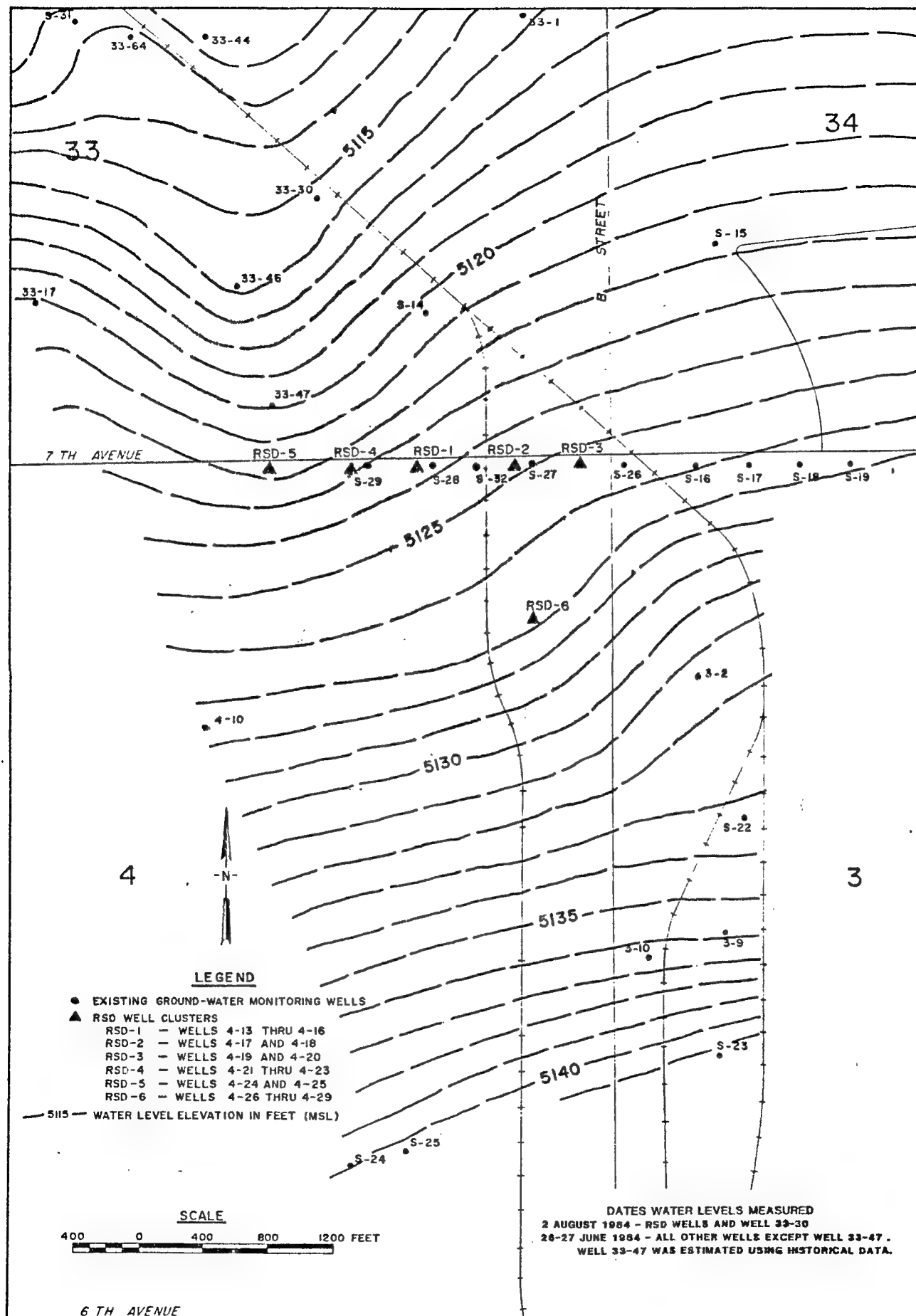


Figure 6. Water table elevations

water level measurements were taken by WES personnel on 2 August 1984. The flow direction portrayed in Figure 6 is to north-northwest which is similar to the previously compiled maps. The irregularities in the area of wells 33-46, 33-30, and 33-64 could be caused by survey errors. Since a 1-ft contour interval was used, any survey error would be amplified. Drawdown by the Adams County pump wells west of 33-30 could cause the irregularities at well 33-30, but survey errors appear to distort this effect on the larger Irondale map. Contour lines show the flow of ground water from the railyard area is through the area around RSD-4, RSD-1, RSD-2, and then toward 33-30.

### Chemical Analysis

#### Irondale study

The study entitled "Evaluation of Shell Chemical Company's Ground-Water DBCP Control System, Rocky Mountain Arsenal, Colorado," was initiated in November 1981 and is presently active. During the Irondale study water quality samples have been analyzed for DBCP for seven periods through 1983. The results of the Irondale study identified one plume in the area around well S-23 (railyard plume) and another plume in the area around the control system (control system plume). The southern part of the control system plume was in the vicinity and included well 33-30 (Figure 1). The only contaminant concentrations found between the two plumes were in wells S-28 and S-27. Concentration levels in well S-28 were 0.30 ppb in May 1982 and 0.33 ppb in September 1983. In well S-27 the contaminant level was 0.22 ppb in January 1982. These data were insufficient to reliably connect the two plumes.

#### Current chemical results

The wells at cluster sites RSD-1 through RSD-6 were sampled on 2 August 1984 and the results are presented in Table 2. DBCP was found in all of the wells at cluster sites RSD-1 and RSD-6, but was not found in wells at cluster sites RSD-2, RSD-3, RSD-4, and RSD-5. The DBCP concentration at cluster site RSD-1 was 2.65 ppb, 4.93 ppb, 3.46 ppb, and 0.73 ppb in wells 4-13, 4-14, 4-15, and 4-16, respectively, and at cluster site RSD-6 was 16.8 ppb, 2.43 ppb, 0.87 ppb, and 0.7 ppb in wells 4-26, 4-27, 4-28, and 4-29, respectively. Well numbers in each cluster site increase with depth. Data from wells sampled by RMA from 3-13 July 1984 and the data from the shallowest well in each RSD

cluster were used to construct a Nemagon concentration map (Figure 7). Figure 7 shows a narrow, elongated plume extending from well S-23 to the northwest through wells RSD-6, RSD-1, 33-30, and towards the control system. The Nemagon concentration decreases from 58.0 ppb at well S-23 to 16.5 ppb at RSD-6 (well 4-26) to 2.65 ppb at RSD-1 (well 4-13) to 1.48 ppb at well 33-30 to 1.31 ppb at well 33-44. The RSD-1 and RSD-6 clusters are the only areas in the plume where the entire thickness of the alluvial aquifer is screened. The data from the wells in each of the clusters (RSD-1 and RSD-6) show the Nemagon concentrations decrease with depth except for well 4-13 (RSD-1) (Table 2).

#### Soil sample odor

During the drilling operation, chemical odors were detected in soil samples from borings RSD-3, RSD-4, RSD-5, and RSD-6 (wells 4-20, 4-23, 4-25, and 4-29, respectively). Sample depth where odors were detected are shown on Figure 4. Two soil samples from boring RSD-3 (samples 4 and 9) were analyzed for volatiles (see Figure 4 for sample depth). In the analysis procedure a sampling tube containing 50 percent charcoal/50 percent tenax was inserted into the plastic bag containing the soil sample and pumped with a vacuum pump for approximately 15 minutes. Each of the samples collected by the vacuum pump was analyzed by Gas Chromatograph/Mass Spectrometer. Sample 4 contained methylene chloride, acetone, trichlorofluoromethane (Freon 11), chloroform, 1,1,2-trichloro-1,2,2-trifluoromethane (Freon 113), methylethyl ketone, benzene, hexane, toluene, ethylbenzene, xylenes, and unidentified hydrocarbons. Sample 9 contained methylene chloride, acetone, benzene, hexane, toluene, ethylbenzene, xylenes, and unidentified hydrocarbons. No quantitative analysis was run.

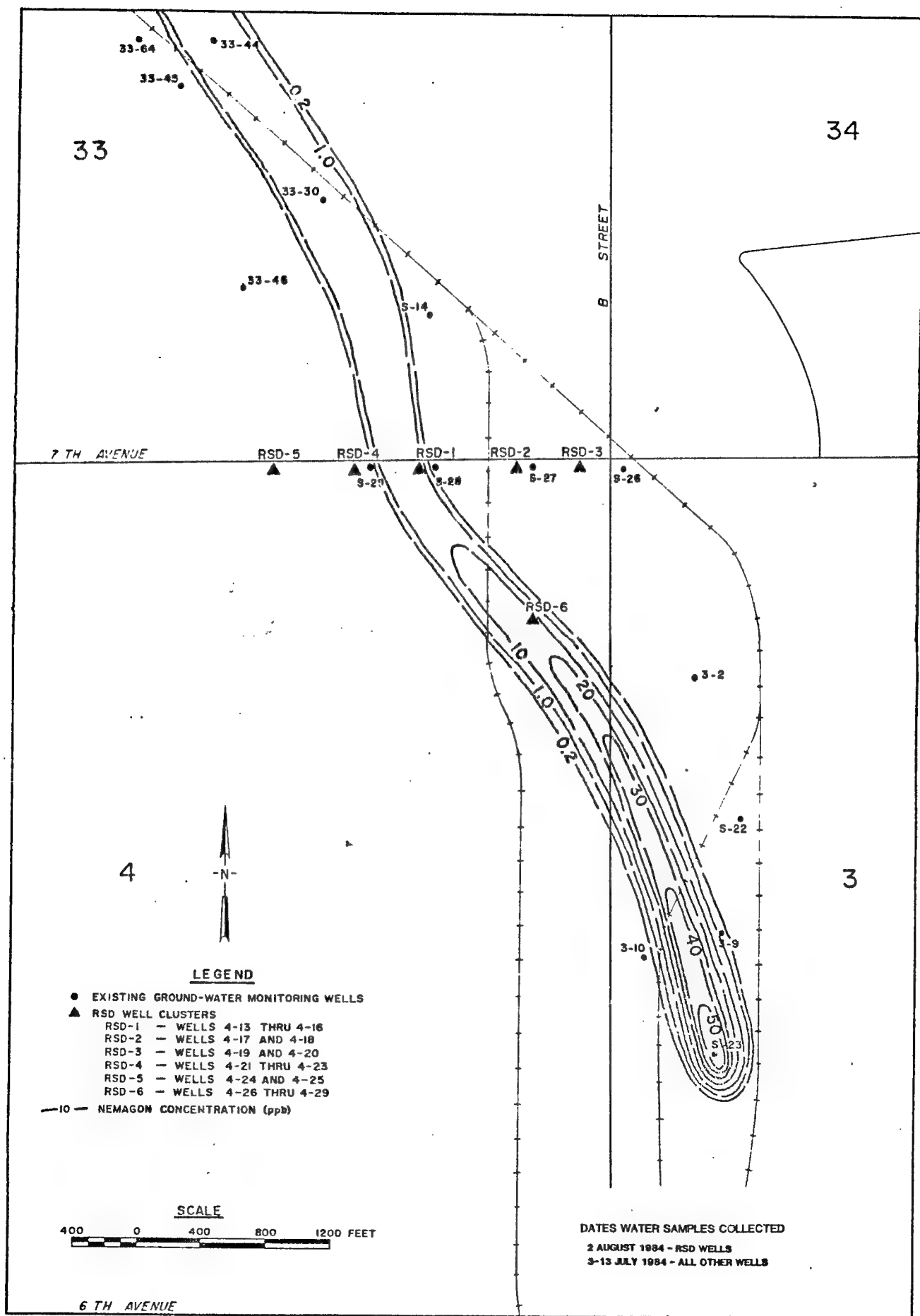


Figure 7. DBCP plume map

## PART IV: CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

The following conclusions were reached as a result of the data analyzed during the study:

a. The chemical data from the RSD well clusters indicate one continuous Nemagon plume extending from the area of well S-23 to well 33-30 and northwest to the DBCP Control System in section 33 and not two separate plumes.

b. The railyard area in section 3 is the primary and probably the only Nemagon source area in the study area.

c. The Nemagon plume extends vertically from the water table to the base of the aquifer (top of the Denver formation) at the RSD-1 and RSD-6 cluster sites.

d. The alluvial aquifer could be contaminated by the chemicals found in the soil samples at the RSD-3 cluster site (well 4-20). Chemical odors were detected in samples from the RSD-4 (well 4-23), RSD-5 (well 4-25), and RSD-6 (well 4-29) cluster sites.

e. Insufficient data are available immediately around S-23 to determine the vertical and lateral limits of the Nemagon source.

### Recommendations

Based on the conclusions of this study, the following activities are recommended:

a. A boring program should be designed to define the vertical and lateral extent of the Nemagon source. The borings should be made on a square grid pattern with well S-23 as the center of the grid network. The spacing of the grid centers will be dictated by the location of buildings and railroad tracks. Drilling should be initiated on the external junctions of the grid. Monitoring wells should be installed at selected boring locations. Chemical analysis from the soil samples and ground water should identify the lateral and vertical extent of the Nemagon source.

b. A study should be initiated to determine the magnitude of chemical contamination other than Nemagon that may be present in the area along 7th Avenue that was identified by the odor found in the RSD soil samples.

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May, J. H. 1982. "Regional Study of Rocky Mountain Arsenal, Denver, Colorado," Report 1, Hydrogeological Definition, US Army Engineer Waterways Experiment Station, CE, Vicksburg, MS.

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Table 1

Well Cluster	Well Number	Elevation (msl)		Water Table		Denver Formation		Screened Interval	
		Top of Casing	Ground	Depth	Elevation	Depth	Elevation	Depth	Bottom Elevation
RSD-1 -1A -1B -1C	4-16	5193.78	5191.4	--	--	100.2	5091.2	91-101	5090.4
	4-15	5193.75	5191.4	70.50	5123.25			81-91	5100.4
	4-14	5193.71	5191.4	--	--			71-81	5110.4
	4-13	5193.77	5191.4	--	--			61-71	5120.4
RSD-2 -2A	4-18	5188.56	5186.3	--	--	82.0	5104.3	71.5-81.5	5104.8
	4-17	5188.27	5186.4	63.87	5124.40			61.5-71.5	5114.8
RSD-3 -3A	4-20	5188.20	5186.0	63.15	5125.05	79.0	5107.0	69-79	5107.0
	4-19	5188.27	5186.2	--	--			59-69	5117.0
RSD-4 -4A -4B	4-23	5194.35	5192.4	--	--	100.4	5092.0	90-100	5092.4
	4-22	5194.13	5192.2	71.65	5122.48			80-90	5102.4
	4-21	5194.38	5192.3	--	--			70-80	5112.4
RSD-5 -5A	4-25	5193.29	5191.4	--	--	86.3	5105.1	75-85	5106.4
	4-24	5193.60	5191.2	71.87	5121.73			65-75	5116.4
RSD-6 -6A -6B -6C	4-29	5193.11	5191.0	--	--	99.0	5092.0	89-99	5092.0
	4-28	5193.02	5191.2	--	--			79-89	5102.0
	4-27	5193.17	5191.3	66.20	5126.97			69-79	5112.0
	4-26	5193.28	5191.3	--	--			59-69	5122.0

Table 2

CLUSTER SITE	USER NUMBER	IDENT- IFIER <sup>1</sup>	LAB NUMBER	COLL DATE <sup>2</sup>	TEST DATE	TEST NAME	ME- TH	BO- OL	VALUE	UNITS	QC PROGRAM
RSD - 1	GJ0687	S04016	A37715	84219	84221	DBCP	R1		.73	UGL	...QUAN
	GJ0688	S04015	A37716	84219	84221	DBCP	R1		3.46	UGL	...QUAN
	GJ0689	S04014	A37717	84219	84221	DBCP	R1		4.54	UGL	...QUAN
	GJ0690	S04014	A37718	84219	84221	DBCP	R1		4.93	UGL	...QUAN
	GJ0691	S04013	A37719	84219	84221	DBCP	R1		2.65	UGL	...QUAN
RSD - 4	GJ0692	S04023	A37720	84219	84221	DBCP	R1	LT	.2	UGL	...QUAN
	GJ0693	S04022	A37721	84219	84221	DBCP	R1	LT	.2	UGL	...QUAN
	GJ0694	S04021	A37722	84219	84221	DBCP	R1	LT	.2	UGL	...QUAN
	GJ0695	S04021	A37723	84219	84221	DBCP	R1	LT	.2	UGL	...QUAN
RSD - 6	GJ0696	S04025	A37724	84219	84221	DBCP	R1	LT	.2	UGL	...QUAN
	GJ0697	S04024	A37725	84219	84221	DBCP	R1	LT	.2	UGL	...QUAN
	GJ0698	S04024	A37726	84219	84221	DBCP	R1	LT	.2	UGL	...QUAN
RSD - 8	GJ0699	S04029	A37727	84219	84221	DBCP	R1		.7	UGL	...QUAN
	GJ0700	S04028	A37728	84219	84221	DBCP	R1		.87	UGL	...QUAN
	GJ0701	S04027	A37729	84219	84221	DBCP	R1		2.02	UGL	...QUAN
	GJ0702	S04026	A37730	84219	84221	DBCP	R1		16.8	UGL	...QUAN
	GJ0703	S04027	A37731	84219	84221	DBCP	R1		2.43	UGL	...QUAN
RSD - 2	GJ0704	S04017	A37732	84219	84221	DBCP	R1	LT	.2	UGL	...QUAN
RSD - 3	GJ0705	S04020	A37733	84219	84221	DBCP	R1	LT	.2	UGL	...QUAN
	GJ0706	S04019	A37734	84219	84221	DBCP	R1	LT	.2	UGL	...QUAN
	GJ0707	S04020	A37735	84219	84221	DBCP	R1	LT	.2	UGL	...QUAN

NOTE : WELL 4-18 (RSD-2) WAS NOT SAMPLED .

1 - IDENTIFIER IS THE WELL NUMBER (S04016 IS WELL 4-16) .

2 - COLL DATE IS 2 AUGUST 1984 .